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**HUMAN RESOURCES**

SKILL MAINTENANCE:  
SPECIFIC SAMPLE METHODOLOGIES

Alice F. Healy  
Lori Meiskey  
David W. Fendrich  
Robert J. Crutcher  
William Little  
Lyle E. Bourne, Jr.

Institute of Cognitive Science  
University of Colorado  
Boulder, Colorado 80309-0345

TRAINING SYSTEMS DIVISION  
Brooks Air Force Base, Texas 78235-5601

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BROOKS AIR FORCE BASE, TEXAS 78235-5601**

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Training Systems Division

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Alice F. Healy  
Lori Meiskey  
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Institute of Cognitive Science  
University of Colorado  
Boulder, Colorado 80309-0345

TRAINING SYSTEMS DIVISION  
Brooks Air Force Base, Texas 78235-5601

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Training Systems Division

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## SUMMARY

Most jobs involve a variety of skills that must be learned. However, variability in job demands may lead to periods when some skills are not used and hence deteriorate. Little research has been done on this process of deterioration. In this paper we propose a number of sample methodologies for investigating the retention of skills ranging from perceptual to motoric to cognitive. These methodologies are based on a theoretical analysis of the existing literature on skill acquisition. Research employing these methodologies should allow for testing hypotheses about skill maintenance and should lead to practical recommendations for training procedures that will optimize skill retention.

## PREFACE

This paper presents a set of proposed methodologies to use in the study of skill maintenance. A companion piece (Fendrich et al., 1988), separately published, provides the background for this proposal in the form of a literature review and theoretical analysis of the subject. Together these documents are meant to provide the basis for a research program on skill maintenance. We wish to acknowledge the help of Antoinette Gesi and Debbie Aguiar in the preparation of this paper.

## SKILL MAINTENANCE: SPECIFIC SAMPLE METHODOLOGIES

Even the most routine of military and civilian jobs involve a variety of component skills that must be mastered by a trainee. Day-to-day variations in job demands dictate that the competent worker have ready access to required skills. Particular component skills, acquired during training, might not be activated for use for considerable time periods. Disuse may lead to skill deterioration which, in the extreme, might mean that a skill is no longer functional when needed. Procedures must be developed to maintain skills at functional levels over periods of disuse. Although there has been considerable research designed to develop training procedures for efficient acquisition of skills, relatively little is known about training procedures or refresher techniques that lead to maintenance over time.

In this document, we propose a number of specific methodologies for investigating training conditions and refresher techniques which contribute to skill maintenance. Our methodologies derive from a thorough review of the literature on skill analysis and on the characteristics of skill components associated with high maintenance. These methodologies address a variety of skills, ranging from perceptual to motoric to higher-level cognitive. These methodologies will allow us to explore conditions of training for a variety of skills that lead to efficient maintenance and retrieval on demand. In the following sections, we describe several apposite methodologies, along with suggestions for possible research. These methodologies will not only allow us to test hypotheses about skill maintenance but also should lead to precise conclusions and practical recommendations for training procedures.

Target detection. Drawing on methodology developed earlier in our laboratory to study pattern recognition processes in reading (see, e.g., Healy & Drewnowski, 1983; Proctor & Healy, 1985) and drawing on methodology previously developed by Shiffrin, Schneider, and their associates to study controlled and automatic information processing (see, e.g., Schneider & Shiffrin, 1977), we have devised, with the help of Richard M. Shiffrin and Janet D. Proctor, a paradigm in which to investigate the long-term retention of target detection skills. In this paradigm, subjects are exposed to a succession of frame sequences on a CRT screen driven by a PDP 11 computer. Each sequence includes 52 frames, each of which is exposed for a fixed duration (1.5 sec). Every frame includes 16 alphanumeric characters and symbols plus two intermediate blank spaces arrayed horizontally to resemble three words of text. (Actually, any of a variety of stimulus configurations, including complex waveforms, can be used.) Half of the frames in every sequence of 52 include a target, and half do not. There are three frame sizes, which are manipulated by varying the number of noise symbols (signified by #). Frame size 16 includes 16 alphanumeric (or other) characters and no noise (e.g., QXR NPLGN RTCBAIEX); frame size 4 includes 4 alphanumeric characters and 12 noise characters (e.g., Q#R ##L## #T#####); and frame size 2 includes 2 alphanumeric characters and 14 noise characters (e.g., ##R ##### #T#####). Every block of 3 successive sequences of 52 frames includes one of each frame size, in a random order. For subjects in the consistent mapping condition, the alphanumeric characters are randomly selected letters and the target is fixed across blocks (say the letter H), whereas for subjects in the varied mapping condition, different targets are used across blocks (so, for example, H is sometimes the target and sometimes a distractor). Subjects respond by pressing a key whenever they detect a target, and both their speed and accuracy are recorded by the computer.

We have devised three tests to assess the degree of skill training attained by a subject. Two of these tests make use of criteria developed by Schneider and Shiffrin (1977). Both of these tests address differences in error rates and response latencies for the three frame sizes. Initially, speed and accuracy are steep functions of frame size, but as training progresses, the slopes of the functions decrease for the consistent mapping condition, but not for the varied mapping condition. The first criterion, defining the attainment of skill automatism, is the point at which the slope in the consistent mapping condition is significantly less steep than that in the varied mapping condition. The more stringent criterion, defining the perceptual "pop out" phenomenon (see, e.g., Treisman & Paterson, 1984), is the point at which the mean error rates and response latencies for the three frame sizes are approximately equal. The third test we developed makes use of the observation that subjects, in performing an analogous letter-detection task with text presented on a terminal screen three words at a time (see, e.g., Proctor & Healy, 1985), typically make many more errors and respond much more slowly when a target occurs in a highly familiar configuration (like h in the word the) than in a less familiar configuration (like h in thy). This pattern of errors has been attributed to the subjects' unitization of familiar visual configurations. In pilot work with this paradigm, we found that after a period of training insufficient for the automatism criterion (approximately 4 hours), subjects showed a dramatic change in their pattern of errors in the target-detection task, so that the large difference between targets (e.g., letters) in common and rare configurations (e.g., words) was eliminated. Hence, our third training criterion will involve elimination of the unitization effects in a test sequence (e.g., a prose passage).

Different groups of subjects will be trained to each of the three criteria in an initial study. We will then allow a long (6-month) retention interval to elapse, at which point subjects will be retested and retrained. We expect that subjects trained to the less stringent unitization criterion will be less likely than the other groups to maintain their level of performance across the long retention interval and that they will no longer be able to meet the unitization criterion (they will once again make more detection errors on familiar configurations than on unfamiliar configurations in the test passage). However, if automatism does indeed lead to skill permastore, as proposed in our first hypothesis, then those subjects trained to the automatism criterion may not deteriorate in performance, as assessed either by the slopes of their reaction time and error functions or by their pattern of responses in the test prose passage. The "pop out" criterion, representing a still more stringent criterion, ought to lead to equivalent or possibly even superior skill retention.

The details of the retraining portion of this experiment depend on the retention outcome. Retraining is pertinent only under conditions of skill deterioration. In the retraining phase, we are primarily interested in the savings afforded by the various original training criteria. This phase will also allow us, however, to look at transfer effects remaining after periods of disuse (see, e.g., Rabbitt, Cumming, & Vyas, 1979), by examining performance on targets that are similar but not identical to those used originally (e.g., h instead of H or T instead of H), and at the effects of retraining with only a subset of the targets originally trained.

Mental calculation skills. A review of the literature has shown that a simple measure of knowledge retention at the end of training is not an adequate



predictor of long-term retention, either quantitatively or qualitatively. The purpose of this study is to determine whether a measure of skill automatism derived from the work of Shiffrin and Schneider (1977) can aid in predicting long-term retention. The Shiffrin and Schneider framework leads to the definition of automatism as the degree to which difficult operations can be performed as accurately and as quickly as simpler ones, or the slope of the functions denoting the relationship between accuracy or speed of solution and problem difficulty. In this study, we will examine the skill of mental multiplication, although this paradigm can easily be applied to other calculational skills such as base conversion or linear algebra problems. It is predicted that an automatism index will prove to be a better predictor of long-term retention than an index based on overall performance levels such as percent correct or mean response latency.

All subjects will begin a training period on solving multiplication problems. Single-digit multiplication problems will be presented on a CRT screen, along with an answer which is either correct or incorrect. Subjects will respond by pressing one of two buttons to indicate whether the solution is correct or incorrect. It is predicted that initially subjects will be less accurate and slower in verifying the answers to problems with larger-digit operands than with smaller ones (the slope of the performance/difficulty functions will be very steep). Based on the theory of automatism, as the training progresses subjects' performance will not only improve overall but the relative difference between the simple and the difficult problems will decrease (the performance/difficulty functions will become much flatter). After training is terminated, an interval of 6 months will expire, followed by a retention test in the same paradigm.

In the first phase of this study, total training time will be fixed and the final levels of performance, by both overall and automatism standards, will be compared in their abilities to predict long-term retention. It is expected that the automatism measure will be a better predictor of retention than will the overall performance level. The data obtained from the first phase will be used to estimate the level of performance at the end of training necessary to retain the skill at a given, high level. This method is similar to that used by Bahrick (1984), except that he estimated optimal study time rather than optimal study performance. Optimal performance estimates will be obtained for both overall performance levels and the slope of the performance/difficulty functions.

In the second phase of this study, a new group of subjects will be given the same training but training will be terminated when performance reaches either the overall or automatism criteria estimates obtained from the first phase. Half of the subjects will terminate training when one criterion is reached and half when the other criterion is reached. After the 6-month interval, subjects will be tested for retention. Our hypothesis is that retention will be best predicted by the automatism measure (the slope of the performance/difficulty functions), regardless of the total training time or the overall level of speed and accuracy attained. Further, the degree to which final retention performance in the second phase matches the level predicted from the first phase will be used to determine the validity of the estimation procedure. If the validity of this procedure is established for this simple skill, we will apply this method to more complex skills to predict the long-term retention of the various components comprising the skills. Further, this technique can be used to predict optimal time intervals for refresher

training.

Calculational word problems. Are procedures better retained or more likely to appear in permastore after discovery or after expository learning? Which method of learning would provide for better transfer of knowledge to novel problems? These are questions which address the long-debated issue of whether discovery or expository learning is better (i.e., makes information easier to retrieve from memory and to transfer to new situations). Bruner (1961) argued that discovery learning is beneficial for a variety of reasons, such as the fact that discovery causes the learner to organize the material, which would lead to better retrievability than if the material were rote memorized. Also, discovery would allow the learner to form an hierarchically higher-level conceptualization of the material; it also might cause the learner to find alternate solutions to a problem rather than merely the "right way to do it," which would provide flexibility in problem-solving ability and would aid in transfer to different situations. Friedlander (1965), on the other hand, provided a number of arguments against the superiority of discovery learning. He noted that there are skills and facts which must be memorized before a larger body of knowledge can be learned. Skills and facts, after being memorized, may yield higher-level conceptualizations. For example, a student may memorize and use the equation  $E = MC^2$  mechanically, but after a period of time realize that the equation means fundamentally that matter is energy. Also, discovery learning takes more time than does expository learning, and the learner may be led to wrong or inappropriate conclusions.

McDaniel and Schlager (1985) attempted to determine if and under what conditions discovery learning was superior to expository learning. They used the domains of water-jar and river-crossing problems. In these problems, there is a general strategy, which is an abstract rule that leads to problem solution, and the procedures which are the specific moves that lead to the solution. Discovery during training caused subjects to solve the transfer problem faster than subjects trained expositively, but only if the same kind of information (strategy or procedures) had to be discovered in transfer as was discovered in training. In these cases, subjects solved the transfer problems faster than subjects trained expositively, but they made the same number of moves to get to the solution. McDaniel and Schlager interpreted these results as indicating that when subjects had to discover procedures or strategies in training, they found which routes resulted in dead-ends, as well as those that worked, and this information was carried over into the transfer problem. Thus, discovery subjects learned how to search efficiently and where to stop a search.

We intend to determine if these results generalize to other more complex and natural domains. One domain we would like to investigate is that of calculational problems. Problems in this domain have a general strategy (i.e., the underlying equation), and procedures to get to the solution (i.e., matching specific instances to variables, solving the equation). We will first try to replicate McDaniel and Schlager's results by having subjects in training discover or not discover strategies or procedures, to see if discovery aids in transfer. We will then test their hypothesis that discovery aids subjects in finding efficient search methods; if it does, then subjects who go through the same steps (correct steps as well as errors) as discovery subjects should solve problems as quickly as the discovery subjects. We will have one group of subjects solve a set of algebra problems (i.e., discover the solutions) expressed in simple stories (word problems). We will have this group write

down each step, including searches which lead to dead-ends. We will then give these procedures to a second group of subjects, and have them use these procedures to solve the same problems. We will then test both groups on transfer problems, and measure their solution times. If the only advantage due to discovery were that of finding efficient search strategies, then the groups should solve the transfer problems in the same amount of time and with similar error patterns. If discovering the solutions in training has some other advantage, then the discovery group should solve the transfer problems faster and more efficiently than the non-discovery group. We hope that this test will provide information about what type of learning yields the best transfer to new problems. Subsequently, we will examine the possible long-term retention of the skills involved in calculational word problems, looking for components which remain specifically a part of permastore.

Memory for item, temporal, and spatial information. We have devised a laboratory analogue of the procedural task involved in diagnosing possible faults in an electronic circuit. The procedural task includes at least three identifiable memory components: the nature of the tests themselves, the temporal sequence in which the tests are applied, and the spatial locations at which the tests are executed. Likewise, the laboratory analogue requires memory for three types of information: item information specifying the identity of each of the to-be-remembered stimuli, temporal order information specifying the time sequence in which the stimuli occurred, and spatial order information specifying the relative positions of the stimuli or the arrangement of the stimuli in space.

The laboratory analogue is based on an experimental paradigm we developed earlier to study short-term retention (see, e.g., Healy, 1974, 1975, 1977, 1978, 1982; Till, Healy, Bourne, & Cunningham, 1986). In this paradigm, subjects are shown a short list of letters which occur one after another in a set of spatial locations arranged in a horizontal linear array. Only one letter is shown at a time and the letters do not usually appear from left to right so that the temporal sequence does not usually correspond to the spatial arrangement. For example, the subject might see first the letter B in the middle of three positions, then the letter S in the right-most position, and last the letter K in the left-most position. The letter identities are B, K, and S; the temporal sequence is BSK; and the spatial arrangement is KBS. Three different conditions are employed in order to examine separately memory for the three kinds of information. In the item condition, the temporal-spatial arrangement of the letters does not vary across trials (e.g., the first letter might always occur in the middle position, the second letter in the right-most position, and the third letter in the left-most position, as in the earlier example); only the identities of the letters change from trial to trial. For example, the letter identities may be B, K, and S on one trial, and M, R, and S on another trial. In contrast, in the temporal condition, the letter identities are fixed across trials, as is the spatial arrangement of the letters (e.g., the letters shown might always be B, K, and S, with B in the middle, S on the right, and K on the left); only the temporal sequence changes from trial to trial. For example, the temporal sequence may be BSK on one trial and BKS on another trial. Finally, in the spatial condition, the letter identities are fixed across trials, as is their temporal sequence (e.g., the letters shown might always be B, K, and S, with B first, S second, and K third); only the spatial arrangement changes from trial to trial. For example, the spatial arrangement might be KBS on one trial and KSB on another.

With item, temporal, and spatial information separated in this way, a number of crucial differences have been found in the characteristics of short-term retention for the three types of information. For example, Healy (1975) found evidence for phonemic coding and a steep time course of forgetting in temporal recall but not in spatial recall. Further, more recently, Till et al. (1986) found evidence for age deficits in spatial recall but not in item recall, with temporal recall showing intermediate age effects. It is likely that the three types of information will also show important differences in their long-term retention and maintenance.

In order to study long-term retention and maintenance of information, the paradigm devised to study short-term retention will be modified in several ways. First, and most crucially, longer retention intervals will be used. The previous short-term recall experiments involved retention intervals varying from 0 to 30 seconds; the present investigation will involve study-test retention intervals ranging from 30 seconds to 30 minutes and test-retest maintenance intervals ranging from 1 day to 1 year. Second, longer lists will be used and a correspondingly greater number of spatial positions. In the previous studies of short-term retention, list lengths varied from three to five items, whereas in the present case, we propose to employ lists 20 items in length. Third, instead of using letters as to-be-remembered items, words will be employed, so that the stimuli will be more meaningful than those used previously. Fourth, the fixed order of the words (the temporal sequence in the spatial condition, the spatial arrangement in the temporal condition, and both the temporal and spatial orders in the item condition) will always correspond to the alphabetical order, to ensure that the fixed order will not be forgotten by the subjects (see, Healy, 1977, for a similar manipulation). More specifically, the subjects will be given lists of words, each of which begins with a different one of the 20 consonants in the alphabet (a, e, i, o, u, and y are excluded). For example, a typical list might be: ballot, charter, deacon, fairy, gesture, hiccup, javelin, kitchen, leopard, motion, newsprint, pilgrim, quarry, rubbish, silver, table, virtue, window, xenon, and zombi. In the item condition, subjects must learn and remember the specific words shown on a trial but will know in advance that the words will be presented in alphabetical temporal sequence and alphabetical spatial arrangement. In the temporal condition, the subjects will know in advance which words will be shown and that the words will be arranged in an alphabetical spatial arrangement; however, they must learn and remember the temporal sequence of the words. In the spatial condition, the subjects will know in advance which words will be shown and that the words will be displayed in an alphabetical temporal sequence, but they must learn and remember the spatial arrangement of the words. In each condition, subjects will learn a single list of words to the criterion of two successive correct recall attempts.

We expect that the long-term retention characteristics of the three types of information will vary, and we suspect that the optimal conditions for maintaining the three types of information will vary, but it is not clear precisely what form the variation will take. Perhaps, for example, as in the case of short-term retention, temporal information will show a steep time course of forgetting. But it may be that phonemic coding will not provide the basis for long-term temporal order recall, in which case the time course of forgetting may be no greater for temporal than for spatial information.

Dual task. The dual-task paradigm (e.g., Posner & Boies, 1971) has been used to assess attentional demands and the attainment of automatism during

skill acquisition (see, e.g., Spelke, Hirst, & Neisser, 1976). Likewise, we have developed a dual-task paradigm to evaluate the attentional requirements of a skill during its acquisition, retention, and maintenance phases. We have elected, for our initial studies, to investigate the motor skills involved in learning to type numbers on the keypad of a computer terminal. The primary task will thus be keying-in a three-digit number displayed on the computer terminal screen, and response latency will be the major measure of primary task performance, assuming that response accuracy is at or close to the ceiling of 100% correct. The secondary task we have chosen is word naming, which is known to be automatic for adult subjects. More specifically, three-letter common words will be shown to the subjects immediately below the three-digit numbers on the computer screen, and the subjects will be requested to name the words aloud. Naming latency will be used as the major measure of secondary task performance, again assuming the error rate is minimal.

In order to assess the effects of changing and variable response patterns on the acquisition and subsequent retention and maintenance of the number keying skill, we will compare three different training conditions. In the constant response pattern condition, the nine digits will occur in only three different three-digit patterns (e.g., 158, 629, 473). Thus, every time a given digit (e.g., 5) is to be keyed, it will always be in the same response context (immediately preceded by 1 and immediately followed by 8). In contrast, in the intermediate, or semi-variable, response pattern condition, the nine digits will occur in only three different three-digit combinations, but the permutations of the digits will vary. Therefore, six different response patterns will be used for a single three-digit combination (e.g., 158, 185, 518, 581, 815, 851). Thus, in the semi-variable condition, every time a given digit (e.g., 5) is to be keyed, it will always be accompanied by the same pair of digits (1 and 8), but the sequence of the three digits will vary across trials. Finally, in the fully variable response pattern condition, the nine digits to be keyed will occur in all possible combinations and permutations (e.g., 158, 185, 562, 785, etc.). Thus, in this condition, the context in which a given digit (e.g., 5) occurs is unpredictable and changing from trial to trial. Each of these response pattern conditions will occur both in dual-task format, with a three-letter word accompanying each three-digit number, and in single-task or control format, with no words accompanying the digits. Each subject will participate in only one training condition under both dual-task and single-task formats. Attentional demands of the three conditions will be assessed in part by comparing primary task latency under the two formats (with or without the secondary task). One defining characteristic of automatism will be that the response latency on the primary task is comparable under the two formats. Further, subjects will participate in a baseline condition involving a secondary task which also consists of naming three-letter words. The second defining characteristic of automatism will be that naming latency obtained in the baseline condition be comparable to that obtained as the secondary task variable in the dual-task format of the experimental conditions.

Subjects will be trained over a period of 8 weeks, with two 1-hour training sessions each week. Retention will then be tested after 2, 4, and 6 months, with no practice during the maintenance intervals.

Following the observations of Shiffrin and Schneider (1977) concerning the differences between constant and variable mapping in the acquisition of automatic target-detection performance, we expect that automatism will be

achieved most rapidly in the constant response pattern condition and that automatism will not be achieved in the fully variable response pattern condition; the predictions for the semi-variable condition are less clear, although performance is expected to be intermediate for that condition. In contrast, retention performance is expected to show the reverse pattern. In accordance with Schmidt's (1975) schema theory, we expect that after a long time interval without skill practice, performance will be better under the fully variable or at least under the semi-variable response pattern condition than under the constant response pattern condition. This prediction that variability will enhance skill maintenance is also consistent with Battig's (1979) intratask interference principle.

Generation tasks. A number of experiments have demonstrated that individuals remember material better by generating it themselves rather than simply reading the same material when it is presented to them by an experimenter. In many of these experiments, the stimuli are pairs of words presented to subjects under two conditions: a read condition and a generate condition. In the read condition, a pair of words is presented and subjects read the pair aloud. In the generate condition, a word pair is presented with the first word intact and the second missing one or more letters; subjects must then generate the second word of the pair using the first word as a context. The generation effect, as it has been called, has been demonstrated for a variety of materials, including: words (Donaldson & Bass, 1980; Glisky & Rabinowitz, 1985; Jacoby, 1978; McFarland, Frey, & Rhodes, 1980; Nairne, Pusey, & Widner, 1985; Slamecka & Graf, 1978), sentences (Graf, 1980), meaningful bigrams (Gardiner & Hampton, 1985), and numbers (Gardiner & Hampton, 1985; Gardiner & Rowley, 1984); and the effect has been obtained using semantic, orthographic, rhyming, and other generate rules.

Along with other experimenters (e.g., Nairne & Widner, 1987), we believe that whether one obtains a generation effect or not depends on what is generated, the type of rule used to generate it, and the type of test used to assess retention. Gardiner and Rowley (1984), for example, found that when subjects generated answers to multiplication problems instead of reading answers supplied by an experimenter, subjects recalled the answers much better. However, in an experiment of our own (Crutcher & Healy, 1986), we found that although mentally generating an answer resulted in superior retention compared to simply reading an answer supplied by the experimenter, generating the answer with a calculator did not significantly improve retention over simply reading the problem and answer. Furthermore, when subjects were presented with a correct answer but were told to verify whether the answer was correct or not, retention performance was comparable to when subjects had mentally generated an answer.

These results suggest that the mental operations performed when internally generating the multiplication products were different from those performed during external generation (i.e., using the calculator). Presumably, the subjects who internally generated the answers had to multiply the two numbers together mentally or at least consult their knowledge of the multiplication facts. Later, during recall, they could use these mental operations as cues to help retrieve the answers. The verbal protocols which we collected from half of the subjects support this hypothesis. In most of the correctly recalled answers, subjects recalled the entire problem (e.g.,  $3 \times 6 = 18$ ) or recalled the two multipliers and then used them to cue their recall of the answer. Though it is not clear that verifying answers involves the same mental

operations as generating the answers (because the answer is supplied, it may serve as a priming cue), apparently the operations that occur during verification are also useful as retrieval cues. Producing the answers with a calculator required selecting and pushing the correct keys and reading the answer off the display, but, at test, the mental operations associated with these tasks were apparently not useful in attempting to recall the answers. Given a different sort of retention test, one that specifically tapped the subjects' memory for these operations, one would more likely obtain a retention advantage for the problems performed on the calculator. These results support our hypothesis that the retention benefits associated with generating material oneself depend on: what material is actually generated, how the material is generated, and how retention is assessed.

Given the size and robustness of the generation effect, we propose to use the generation paradigm as a methodology to examine what types of learner-generated material and rules will lead to superior retention under differing test conditions. We suspect that material which is self-generated may often be highly resistant to decay. However, because no experiments have tested whether the retention advantage demonstrated for self-generated material will extend to longer retention intervals, we plan to test this hypothesis in the near future. We then propose to extend the generation paradigm to examine the effects of self-generation for material that would likely be encountered in skill acquisition settings. If this paradigm can be extended to tasks other than simple word completion and arithmetic tasks, it holds promise of being a useful methodological tool for assessing what types of generation tasks lead to optimal long-term retention. Tasks we are considering looking at include: (a) having learners generate the reasons for performing specific task steps instead of supplying them with the reasons, (b) having learners solve problems for themselves instead of providing them with answers, and (c) asking learners to write down in their own words definitions for new vocabulary terms rather than simply giving them the definitions.

Previously learned skills. In order for previously learned skills to be tested and re-trained, a measure of the subjects' initial training and later retention of the skill must be obtained. Examples of previously learned skills are multiplication, finding square roots, and solving algebra equations. A questionnaire, similar to that used by Bahrck (1984), will be used to assess when, how, and to what extent a subject was originally trained in a skill. The questionnaire will also assess the type and amount of maintenance that the skill received after the original training. The general format of the questionnaire will be as follows:

Original Training:

1. When was the skill first learned?
2. What was the performance level immediately after the original training was finished?
3. What strategies were used to memorize the information or operations?
4. What strategies were used to perform the operations?
5. Approximately how quickly could the operations be performed?

Retention and Estimates of Current Performance:

1. How much rehearsal did the skill receive?
  - a. What classes or other training were taken which involved the use of these operations or this information?
  - b. What everyday activities were performed which involved the use of these operations or this information?
2. What strategies, if any, are currently used to perform these operations?
3. Approximately what is the current performance level? (The actual performance level will be measured and may differ from the subject's estimate of his or her ability.)

A sample questionnaire which assesses the skill of multiplication is shown below:

Original Training:

1. When did you first learn the multiplication tables (what year and what grade in school)?
2. To what level did you memorize the multiplication table?  
Never——Up to——Up to——Up to——Up to——Up to——Up to——Over  
Memorized 5x5      9x9      10x10      11x11      12x12      13x13      13x13
3. What strategies did you use to learn the table (e.g., rote memorization, reference to addition)?
4. What strategies did you use when you had to compute the answer to a multiplication problem?
5. Estimate how quickly you were able to answer the following problems when you completed your first year of learning multiplication:  
0-5 sec - 5-10 sec - 10-20 sec - 20-30 sec - 30-45 sec - 45 sec-1 min.
  - a. 5x5
  - b. 7x6
  - c. 9x2
  - d. 6x4

Retention and Estimates of Current Performance:

1. What math courses have you had since you learned the multiplication table?

Grade School

Middle School

High School

College



2. What other math-related courses have you had since you learned the multiplication table (e.g., physical sciences, engineering, statistics)?

|                     |                      |                    |                |
|---------------------|----------------------|--------------------|----------------|
| <u>Grade School</u> | <u>Middle School</u> | <u>High School</u> | <u>College</u> |
|---------------------|----------------------|--------------------|----------------|

3. How often do you use a calculator?

Over once a week — Over once a month — Over once a year — Never

4. How often do you use paper and pencil to do computations?

Over once a week — Over once a month — Over once a year — Never

5. How often do you do computations in your head?

Over once a week — Over once a month — Over once a year — Never

6. List the everyday activities in which you use multiplication, how often you engage in these activities, and how you normally calculate the answers:

| <u>Activity</u>                                    | <u>How often (e.g.,<br/>once per week)</u> | <u>For how<br/>many years</u> | <u>Method<br/>of Calculation<br/>(calculator,<br/>paper &amp; pencil,<br/>or in head)</u> |
|--|--|-------------------------------|---|
| a. shopping  |  |                               |   |
| b. cooking   |  |                               |   |
| c. calculating areas<br>(e.g., wallpaper,<br>rugs) |  |                               |   |
| d. other (please list)                             |  |                               |   |

7. What strategies (if any) do you use now to solve multiplication problems?

8. To what level do you think you know the multiplication table now (without computing the answers)?

Bahrack (1984) used the questionnaire he developed to show what factors influence the retention of Spanish. He found that factors involved in original training predicted retention: Higher grade received and higher level of training (in Spanish and in other Romance languages) indicated better performance on various tests of Spanish knowledge. The amount of time since original training also influenced retention; shorter retention intervals were associated with better retention. The above general questionnaire is predicted to indicate the same effects of training factors on retention: Higher performance at the end of training, higher levels of training, and a shorter interval between training and test should lead to better performance on a

retention test of the relevant skill.

Bahrick also found that rehearsal factors did not predict performance on the retention tests. He stated that this may be due to the fact that most people rehearsed Spanish very little since they were originally trained. The rehearsal factors on the above questionnaire will be used to determine if rehearsal has any effect on retention of a skill. It seems likely that rehearsal will improve retention, and also that some types of rehearsal will aid retention more than others. For example, subjects who compute multiplication problems in their heads should be faster and more accurate than subjects who have mainly used a calculator for computations since original training in multiplication.

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